THE GPR SCANNER AS THE NEXT STEP IN DETAILED 3D DIAGNOSTICS

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Abstract
Georadar (GPR) has gained an important place among other non-destructive methods. Due to its ability to collect huge amounts of data in a short time, georadar can perform detailed 3D surveys of the body under study with a very fine measuring step. For hand-held antenna surveys it is difficult to ensure the exact position of a measuring point. The interpretation of such datasets is therefore impacted by position inaccuracy. A 3D scanner improves the positioning accuracy and helps to extend GPR diagnostics ability. Besides the detailed study of the inner structure of a body, another specific application of GPR scanners is the monitoring of temporal changes in properties of a construction.

In the frame of the R&D project DIBEKON, financially supported by MPO (the Ministry of Industry and Trade), the company INSET s.r.o. is developing a 3D GPR scanner. The prototype of the scanner has recently been tested and an example of GPR scanner measurements is given in the present contribution.

Key worlds: GPR, georadar, scanner, NDT, DIBEKON

1. Introduction
Over last decade, GPR has become a widely accepted (at least in certain countries) and frequently used non-destructive diagnostic method with a large range of applications. It is excellent in metal object detection. Our company participated in research projects focused on comparison tests between different diagnostic methods. Results proved that GPR exceeds other methods, like profometer, impact-echo, etc., in accuracy and reliability in the detection of reinforcement. Other kinds of construction elements and defects can also be detected with GPR, e.g. honeycombs, voids, ducts, etc.. Radar is used to identify the geometric parameters of constructions – layer thicknesses, depth of foundation - as well as the quality of materials and their spatial changes - porosity, humidity, chloride content, etc..
Obviously, radar gives the best results in combination with other non-destructive and destructive methods and tests.

Radar is very fast at collecting data and this allows measurements to be made with a very fine step (centimeters or even less). Progress in computation technologies has allowed the collection and handling of large datasets, and helped to process them with the application of the most advanced mathematical techniques, developed originally for the oil industry. One example of a GPR survey will be given to show the productivity of radar measurements and the quantity of collected data. A 9 km long segment of the water main tunnel supplying Prague with a fresh water
was surveyed with GPR. A multichannel radar unit RAMAC CU-II was used with 2 antennas attached. In two runs (up and back) we were able to scan the cylindrically shaped tunnel wall in a system of 4 parallel lines with measuring step 0.1 m in a time period of 8 hours (one shift). Each GPR profile contained 60 MB of data.

2. 3D GPR surveys

Technological advances have allowed 3D GPR surveys to be conducted. Measurement in such cases is usually carried out in a regular grid of parallel and or perpendicular lines, and the surface of the surveyed structure is densely covered with measurement points in both directions x and y. For processing, not only 2D mathematical filters, but also 3D filters (like 3D migration of data) can be applied. The results can be displayed in the form of x- or y- slices, horizontal scans and or 3D block diagrams. The 3D projection helps to create an idea of the spatial distribution of the detected features inside a structure, and also to detect even weak responses from anomalies. Advanced and more sophisticated interpretation software often has the option to create dynamic animation which helps to travel through a body under investigation. Again, an example of a detailed 3D GPR measurement can be given for comparison. A survey of an area of diameter 1.5 x 2.5 m covered with a 1 cm by 1cm grid of measurement points represents the collection of 37 650 data records (called traces), and creates a file of size 38 MB. The time needed for collecting such an amount of data is ca 2 hours.

An important practical problem for processing 3D data collected by hand lies in an inaccuracy of data-point positioning. Profiles are not kept perfectly straight and measured distances along the line are also not exactly correct. According to our experience, even with great attention paid to the quality of positioning during measurement and with subsequent mathematical correction of line lengths, the accuracy for large scale surveys (tunnel walls, bridge decks, etc.) does not fall below 0.1 – 0.3 m.

Figure 1: GPR survey of the floor and 6 m high walls of the vessel elevator basin, over 150 m long and with inclination 22°, at the Orlik dam. Measurement of the walls was carried out from a hanging gondola. It was difficult to keep the antenna in a straight line and at an exact position. The calculated positioning error of measurement points was about 20 cm.
Although the relative error seems low, in many cases it is impossible to interpolate the position of anomalies between parallel lines. For example, Figure no.2 shows the interpolation of a bar position among parallel lines with 1 m separation. Even though collected data were of a good quality, the interpolated rod is not straight but bent due to an imperfection in positioning. The distance between adjacent reinforcing rods was ca 25 cm, which is more or less the same as the distance positioning error.

Figure 2: Example of a GPR 3D survey of a concrete wall. The GPR cross-section P3 with interpreted positions of bars (above), and the wall section with the position of detected bars and an example of an interpretation of one rod among GPR lines (below)

In such cases, where the quality of data does not allow direct 3D processing, parametric processing can be used instead. With parametric processing we do not asses the position of individual reinforcing bars, but, for example, we evaluate changes in bar separation, we observe variations in cover thickness, or we analyze spatial signal amplitude changes, etc.. As an example, parametric processing of the GPR survey presented in Figure no.1 and 2 is shown in Figure no.3.

There are times when it is necessary to know the exact position of individual reinforcing bars (or other structural elements). In such cases the GPR scanner is an available, and often the only, solution.
3. GPR scanner DIBEKON tests

The principle of a scanner can be simply described as a device in which a GPR antenna is moving automatically inside the frame, fixed to the surface of a structure under inspection, from one pre-defined measurement point to another. The company INSET s.r.o. has been working on the development of such a tool for the last two years, and this summer the prototype of the GPR scanner “DIBEKON” was tested. For testing, technically very difficult measurements were taken at the Orlik dam construction (Vltava River, Central Bohemia). The scanner was fixed to the floor and 6 m high walls of the basin of the vessel elevator, which is 150 m long with a floor inclination of 22°. The frame had to be fixed through the use of mountaineering techniques. A total of six test areas were inspected with DIBEKON during May, June and September 2009.

The installed DIBEKON frame allowed a maximum area of 2.7 x 6 m to be scanned, but usually smaller rectangular areas were sufficient for test purposes. The scanning was automated with lines of separation from 2 to 5 cm and a measurement step ranging from 0.2 to 2 cm. The scanning device has been designed to carry RAMAC GPR system coupled with 800 MHz or 1600 MHz shielded antennas. We have tested measurement setups with lines oriented in either direction, vertically and horizontally, and with the GPR antenna axis oriented parallel or perpendicular to a line direction.
Figure 4: Installation of the scanner frame on a wall of a vessel elevator basin at the Orlik dam.

Figure 5: GPR scanning in progress. This test area No.3 was selected to cover the joint between the wall, and the crown, which was cast later, and sub-vertical shrinkage joint of an irregular shape.
Figure 6: Test area No.3 with interpreted position of detected reinforcing bars (left). It is clear that two concrete blocks were casted separately - reinforcement is not crossing dilatation joint. The crown was poorly reinforced. On the right there is a scan calculated for a depth 5 cm below the surface, showing a difference between cover thicknesses. While reflections from rods placed in the concrete block to the left of the shrinkage joint, with coverage ca 3 - 5 cm, have high amplitude, deeper ones situated to the right, with coverage thickness ca 7 - 9 cm, are hardly visible in this scan.
Figure 7: Results of GPR measurement at test area no.2. Left: scans parallel to surface constructed for depths 12, 14, 16 and 18 cm show position of reinforcing bars at different depth levels. Right: Interpretation chart with drown position of bars and color scale of their cover thicknesses.

4. Conclusions

Radar has been proved to be a very efficient non-destructive testing method. The studied structure can be covered with a dense net of measurement points in a reasonably short time, and due to technological advancement even the large datasets of 3D surveys can be processed and displayed on a PC.

The next step in improving the quality of GPR surveys is the application of the 3D scanner. The company INSET s.r.o. has been developing, and recently has tested, their own device - DIBEKON. The results of the tests prove that GPR can offer a detailed and very precise 3D image of studied structures.

The intention of the author of this paper is to test the ability of the GPR scanner in repeated measurements and in the monitoring of temporal changes (e.g. propagation of weathering processes) of the investigated structure. The vital condition for such kind of tests is the repeatability of measurements related to the exact positioning.
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